Poultry Food Assess Risk Model for Human Pathogens
(Poultry FARM-HP)
Version 1.0

-1998

Thomas P. Oscar, PhD
Research Food Technologist

USDA, ARS
Microbial Food Safety Research Unit
1124 Trigg Hall
University of Maryland Eastern Shore
Princess Anne, MD 21853

410-651-6062
410-651-6568 (fax)
toscar@umes-bird.umd.edu

INTRODUCTION

The Poultry Food Assess Risk Model for Human Pathogens (Poultry FARM-HP) is a collection of computer spreadsheet models developed by Dr. Thomas P. Oscar of the Agricultural Research Service of the United States Department of Agriculture. Version 1.0 of Poultry FARM-HP contains one simulation model and three predictive models. The models are incorporated into Excel notebooks and the simulation model requires @Risk (Palisade Corp., 31 Decker Road, Newfield, NY, 14867; 800-432-7475) to run. Use of the models in Poultry FARM-HP requires a basic knowledge of Excel and @Risk.

The primary goal of Poultry FARM-HP is to provide poultry companies and regulatory agencies with computer models that assist them in making important food safety decisions that impact public health.

SIMULATION MODEL

The simulation model in Poultry FARM-HP assesses the impact of poultry production and processing on the risk and severity of infections from poultry food contaminated with human pathogens (i.e., *Salmonella* and/or *Campylobacter*). The slide presentation in the Appendix describes and demonstrates the models in Poultry FARM-HP.

Operating Instructions

1. Open the Excel notebook Simulate.xls of Poultry FARM-HP.
2. Click on the spreadsheet Tab labeled Model.
3. Red numbers in Simulate.xls are entered by the user, whereas blue numbers are calculated by the model.
4. In the Model spreadsheet, highlight the output cells (B51:B148).
5. Click on the Add Outputs button of @Risk.
6. Enter input settings (red numbers in the Model spreadsheet).
7. Print a copy of the input settings for your records.
8. Click on the Simulation Settings button of @Risk.
9. In the Iteration page of the Simulation Settings box enter 10,000 for the number of iterations.
10. Click on the Sampling page of the Simulation Settings box and select Latin hypercube and enter a random number generator seed of your choice.
11. Exit the Simulation Settings box.
12. Click on the Simulate button of @Risk. The simulation will take about 7 minutes.
13. In the Results window of @Risk, click on Results in the menu bar and then on Reports to Worksheet in the submenu bar.
14. In the Reports to Worksheet box, select Statistics and then OK. The statistical results will be exported to a new Excel workbook.
15. In the Results window of @Risk, click on the Hide button to reveal the new Excel notebook

containing the simulation results.

16. In the newly created Excel workbook, click on the Tab for the Summary Statistics spreadsheet.
17. Highlight the means for the Output cells and then click on the Copy button of Excel.
18. Click on Window in the menu bar and then on Simulate.xls in the Window submenu bar.
19. Click on the Tab of the Results spreadsheet in Simulate.xls.
20. Click on cell B2 of the Results spreadsheet in Simulate.xls.
21. Click on the Paste button of Excel to copy the results of the simulation into the Results spreadsheet of Simulate.xls.
22. Click on the Tab of the Graphs spreadsheet in Simulate.xls to view the results.
23. Print a copy of the Graphs spreadsheet for your records.
24. Enter the public health index data for the simulation into the Stats spreadsheet of Simulate.xls. Note: Scenario A is the baseline scenario, whereas scenarios B to E are test scenarios that are compared to scenario A using a paired t-test.

PREDICTIVE MODELS

Are mathematical equations that predict changes in the number of *Salmonella* on poultry products as a function of variables such as time, temperature, pH, and water activity. Predictive models in Poultry FARM-HP are quadratic polynomial models of the following form:

$$Y = b_0 + b_1A + b_2B + b_3C + b_4AB + b_5AC + b_6BC + b_7A^2 + b_8B^2 + b_9C^2$$

where Y is lag time, specific growth rate, or specific death rate; A, B, and C are food factors such as temperature, pH, or water activity; and b_0 to b_9 are regression coefficients.

Predictive models can be used to define the incidence and extent of pathogen events in the simulation model of Poultry FARM-HP. Poultry FARM-HP contains three models for growth of *Salmonella typhimurium* ATCC 14028. These models predict when (i.e., lag time), how fast (i.e., specific growth rate), and the extent (i.e., log cycle increase) of *Salmonella* growth during temperature abuse of poultry food. In addition, the predictive models in Poultry FARM-HP predict the health outcome of the temperature abuse scenario selected by the user.

Predictive models in Poultry FARM-HP have been validated against data not used in their development. The range of each model parameter used to develop the model are indicated in parentheses following the parameter label in the spreadsheet. When making predictions using a model do not enter values for model parameters that are outside the range used to develop the model as predictions obtained with such values are not reliable.

Model 96D

This model predicts the growth of *Salmonella typhimurium* in brain heart infusion broth as a function of previous growth pH (5.5 to 8.5),. temperature (15 to 40°C), and pH (5 to 7).

Model 97B

This model predicts the growth of *Salmonella typhimurium* on cooked chicken breast and cooked chicken thigh as a function of previous growth temperature (16 to 34°C) and temperature (16 to 34°C).

Model 98A

This model predicts the growth of *Salmonella typhimurium* on cooked chicken breast as a function of previous sodium chloride (0.5 to 4.5%) and temperature (10 to 40°C).

Operating Instructions

1. Open the Excel notebook Predict.xls of Poultry FARM-HP.
2. The Index spreadsheet contains a listing of the models.
3. Red numbers in the models are entered by the user, whereas blue numbers are calculated by the model.
4. Select a model by clicking on the appropriate spreadsheet Tab.
5. Enter values for the model parameters and risk parameters.
6. The model automatically calculates the growth characteristics and health outcomes.

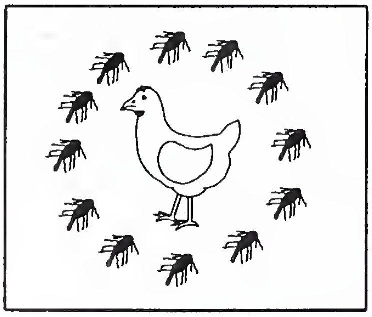
If you have any questions or suggestions regarding Poultry FARM-HP, please do not hesitate to contact me.

Sincerely,

Thomas P. Oscar

Appendix

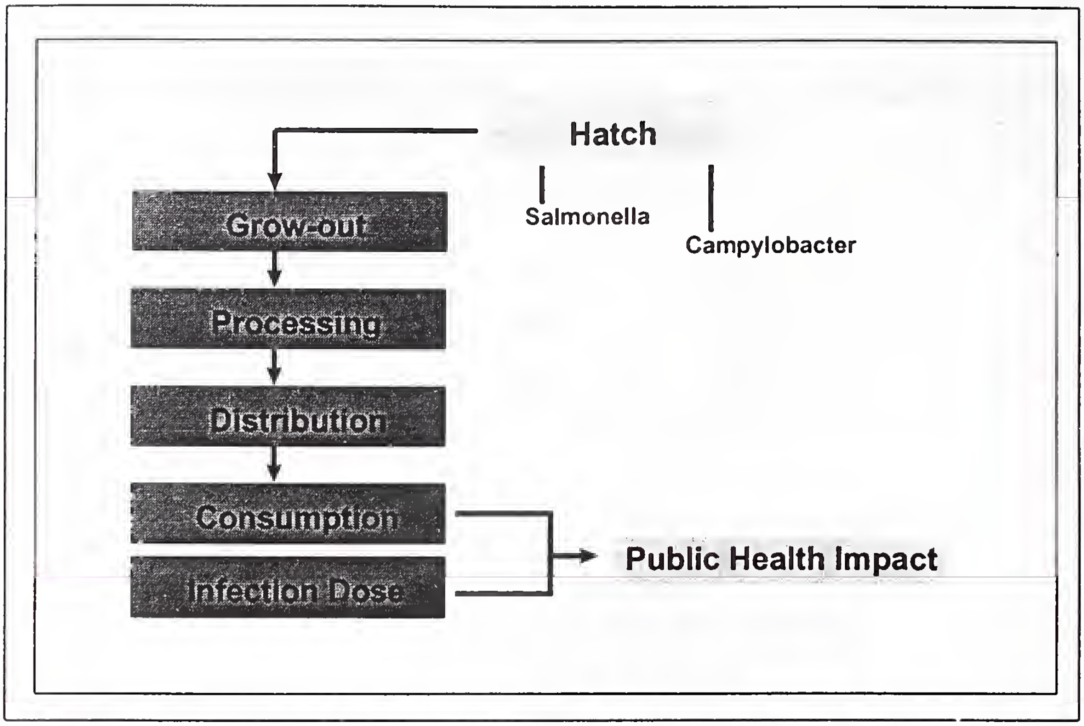
Poultry Food Assess Risk Model for Human Pathogens (Poultry FARM-HP)



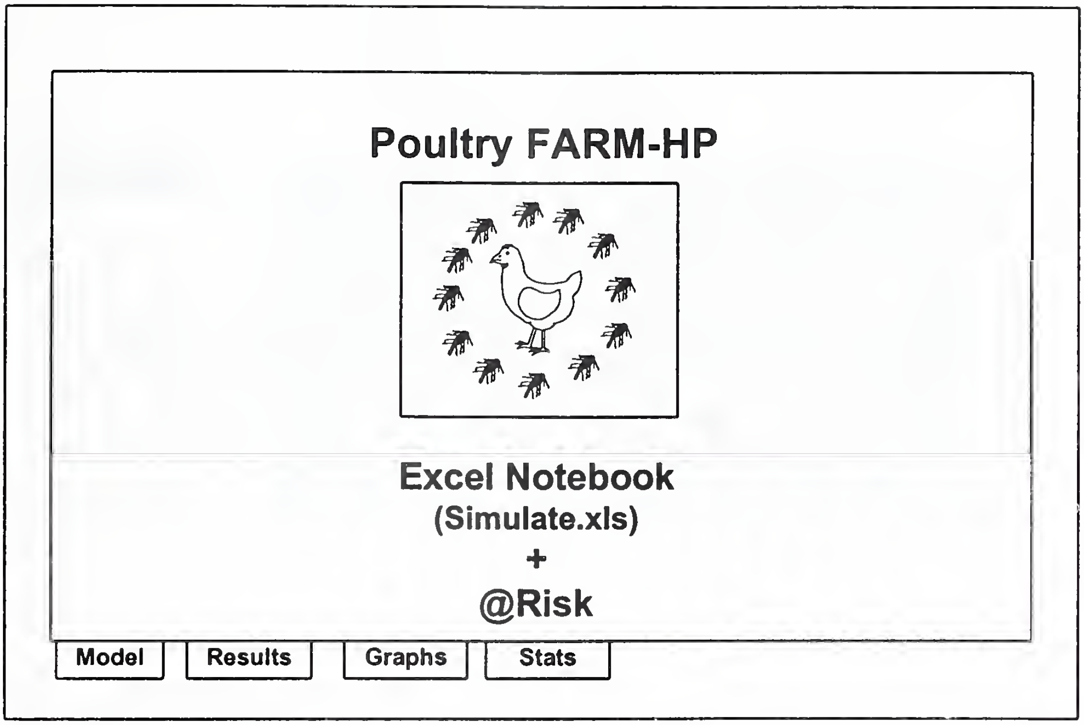
Thomas P. Oscar, PhD
USDA, ARS
Microbial Food Safety Research Unit
University of Maryland Eastern Shore
Princess Anne, MD

Risk assessment models of poultry production and processing systems have great potential for assisting the poultry industry and regulatory agencies in making important food safety decisions that impact public health.

With the advent of computer software programs, such as @Risk, that perform simulations of models created in common spreadsheet programs, such as Excel, it is now possible to create computer models that predict the risk and severity of foodborne disease from poultry produced by specified farm to table scenarios.



In the current presentation, I am going to describe and demonstrate a computer simulation model that assesses the public health impact of poultry production and processing on the risk and severity of Salmonella and Campylobacter infections from poultry food.



The model is constructed in an Excel spreadsheet and is simulated using @Risk, a spreadsheet add-in program.

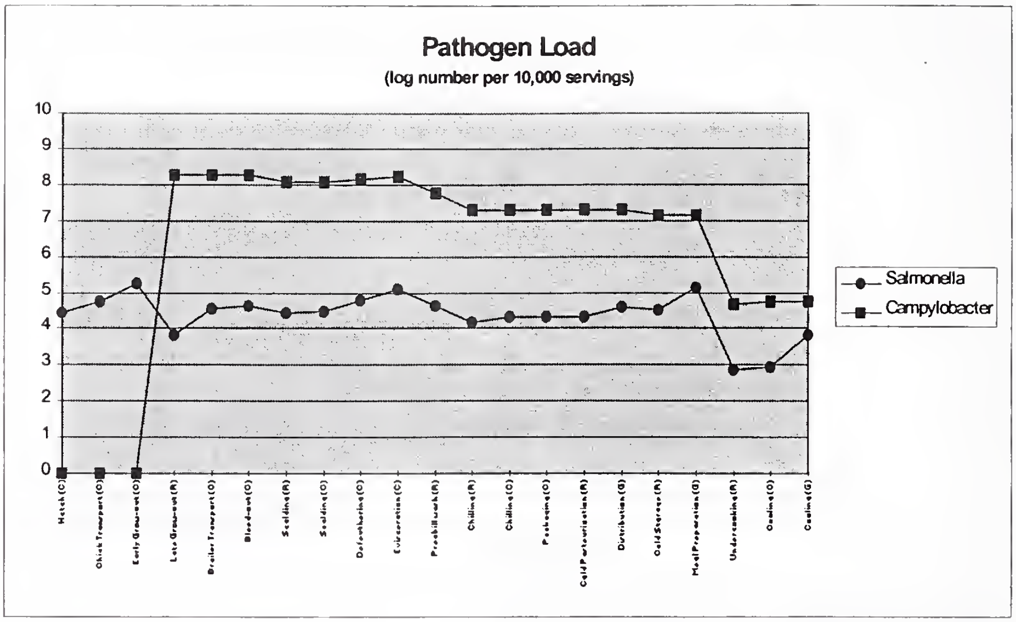
The Excel notebook that houses the model consists of four spreadsheets.

The Model spreadsheet contains the model.

The Results spreadsheet contains formula that convert the model outputs into summary graphs.

The Graphs spreadsheet contains the summary graphs.

The Stats spreadsheet statistically compares different farm to table scenarios.



The third graph shows the change in pathogen load of the poultry food as it moves from hatch to table.

Pathogen load is expressed as the log number of pathogens per 10,000 servings of poultry.

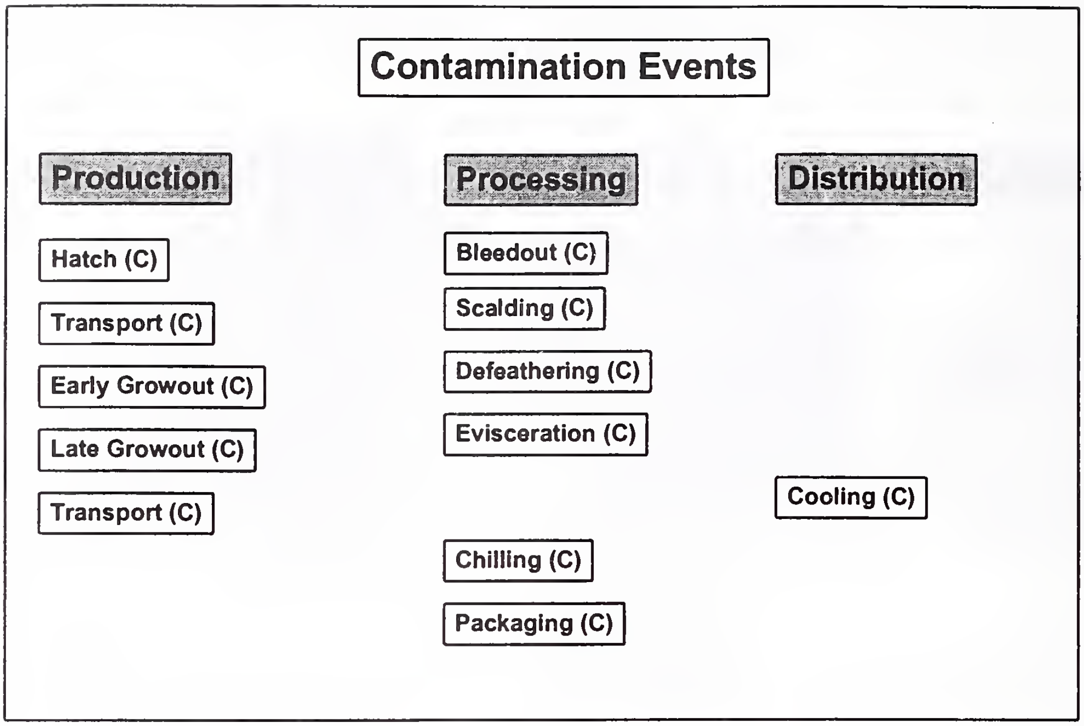
In order to model the impact of poultry production and processing on the risk and severity of human pathogen infections from poultry food, a method had to be developed for modeling the change in pathogen load across the farm to table continuum.

Pathogen Events

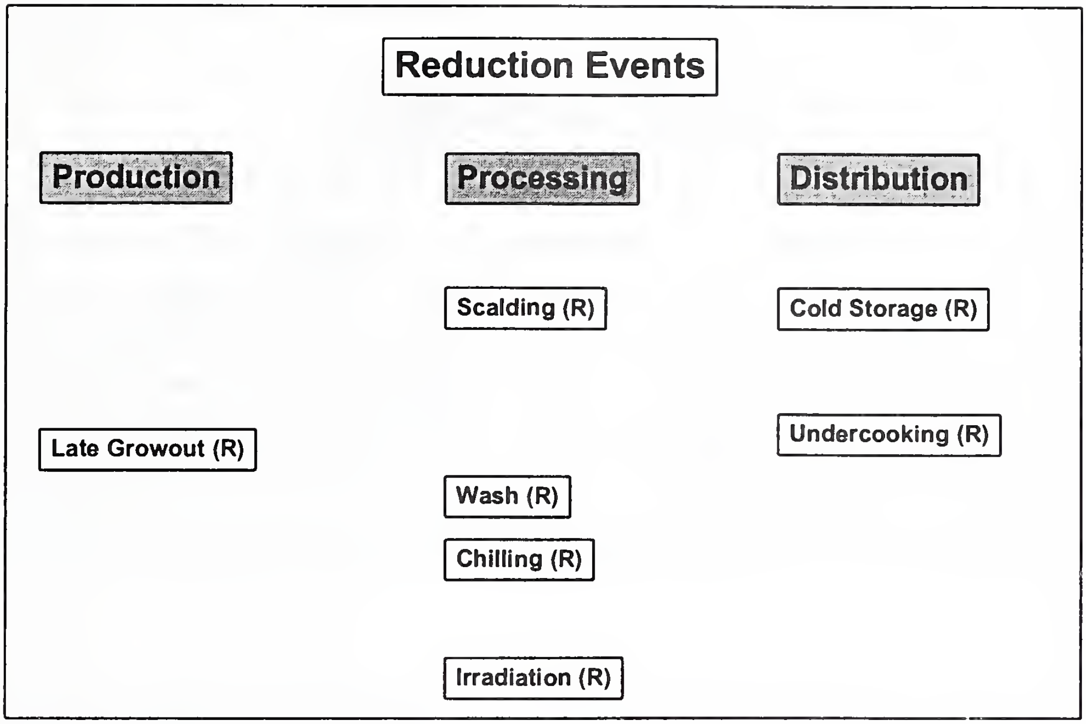
Production	Processing	Distribution
Hatch (C)	Bleedout (C)	Cold Storage (G)
Transport (C)	Scalding (R/C)	Cold Storage (R)
Early Growout (C)	Defeathering (C)	Preparation (G)
Late Growout (R/C)	Evisceration (C)	Undercooking (R)
Transport (C)	Wash (R)	Cooling (C)
	Chilling (R/C)	Cooling (G)
	Packaging (C)	
	Irradiation (R)	

The method developed involved mapping the farm to table continuum as a sequence of pathogen events.

Three types of pathogen events are used.



Contamination events are used to model increases in pathogen load that result from contact of poultry food with contaminated vectors, such as feces, water, equipment, and hands.



Reduction events are used to model decreases in pathogen load that result from physical removal or inactivation of pathogens.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Hatch (C)-Salmonella	5	0	1	3
Hatch (C)-Campylobacter	0	0	3	6
Transport (C)-Salmonella	5	0	1	3
Transport (C)-Campylobacter	0	0	3	6

The first pathogen event in the model is contamination of poultry in the hatchery.

In the baseline model, 5% of the poultry servings are contaminated with between 1 and 1,000 Salmonella, whereas 0% of the poultry servings are contaminated with Campylobacter.

In general, Campylobacter contamination of poultry is not observed until late growout.

After leaving the hatchery, Salmonella contamination of poultry increases during transport to the farm.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Early Growout (C)-Salmonella	20	0	1	3
Early Growout (C)-Campylobacter	0	0	3	6
Late Growout (R)-Salmonella	75	-2	-1	0
Late Growout (C)-Campylobacter	85	0	3	6

A further increase in Salmonella contamination occurs during early growout.

In contrast, during late growout, Salmonella contamination decreases as the birds develop a mature gut microflora and immune system.

Campylobacter contamination occurs for the first time during late growout.

At market age, 85% of the poultry servings are contaminated with high levels of Campylobacter.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Hatch (C)-Salmonella	5	0	1	3
Hatch (C)-Campylobacter	0	0	3	6
Transport (C)-Salmonella	5	0	1	3
Transport (C)-Campylobacter	0	0	3	6

The first pathogen event in the model is contamination of poultry in the hatchery.

In the baseline model, 5% of the poultry servings are contaminated with between 1 and 1,000 Salmonella, whereas 0% of the poultry servings are contaminated with Campylobacter.

In general, Campylobacter contamination of poultry is not observed until late growout.

After leaving the hatchery, Salmonella contamination of poultry increases during transport to the farm.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Early Growout (C)-Salmonella	20	0	1	3
Early Growout (C)-Campylobacter	0	0	3	6
Late Growout (R)-Salmonella	75	-2	-1	0
Late Growout (C)-Campylobacter	85	0	3	6

A further increase in Salmonella contamination occurs during early growout.

In contrast, during late growout, Salmonella contamination decreases as the birds develop a mature gut microflora and immune system.

Campylobacter contamination occurs for the first time during late growout.

At market age, 85% of the poultry servings are contaminated with high levels of Campylobacter.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Transport (C)-Salmonella	5	0	1	3
Transport (C)-Campylobacter	5	0	3	6
Bleedout (C)-Salmonella	1	0	1	3
Bleedout (C)-Campylobacter	1	0	3	6

During transport to the processing plant and during bleed-out, levels of Salmonella and Campylobacter on the edible tissues of poultry increase as a result of contact with contaminated vectors, such as digestive tract contents and equipment.

The extent of these contamination events is set higher for Campylobacter than Salmonella because digestive tract contents usually contain a higher concentration of Campylobacter than Salmonella.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Scalding (R)-Salmonella	100	-0.4	-0.2	0
Scalding (R)-Campylobacter				
Scalding (C)-Salmonella	1	0	1	2
Scalding (C)-Campylobacter	1	0	2	4

During scalding the pathogen load of poultry may increase or decrease.

Consequently, scalding is modeled as a reduction event followed by a contamination event.

The reduction event was modeled by assuming random removal of bacteria by the scald tank water.

Thus, the reduction of pathogens was a probability that was equally applied to Salmonella and Campylobacter.

The contamination event was modeled by assuming that it occurred as the birds were lifted from the scald tank.

Furthermore, it was assumed that digestive tract contents in the water are the primary source of pathogens.

Thus, the extent of contamination during scalding was set lower than previous contamination events because of the dilution and heat inactivation characteristics of the scald tank water.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Packaging (C)-Salmonella	1	0	0.5	2
Packaging (C)-Campylobacter	1	0	1	3
Irradiation (R)-Salmonella	0	-3.0	-2.0	0
Irradiation (R)-Campylobacter				

Further increases in pathogen load of poultry may occur during cut-up and packaging as a result of contamination from equipment and workers hands.

An irradiation event is included in the model to allow evaluation of this technology on food safety.

In the baseline model, the incidence of irradiation is set to 0% indicating that the poultry food was not irradiated.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Cold Storage (G)-Salmonella	40	0	0.1	1
Cold Storage (G)-Campylobacter	0	0	0.1	1
Cold Storage (R)-Salmonella	10	-2.0	-0.5	0
Cold Storage (R)-Campylobacter	40	-2.0	-0.5	0

After the packaged poultry is shipped from the processing plant it may experience temperature abuse during movement through the distribution channel.

It was assumed that the temperature of abuse was below the minimum growth temperature of Campylobacter.

Thus, the incidence of Campylobacter growth was set to 0% throughout the baseline model.

In contrast, it was assumed that 40% of the poultry servings experienced severe enough temperature abuse during cold storage to result in a 0 to 1 log increase in Salmonella numbers.

It is common practice for poultry to be frozen before consumption.

Freezing has been shown to inactivate Salmonella and Campylobacter.

It was assumed that 10% of the poultry servings were frozen before consumption resulting in a 0 to 2 log decrease in pathogen numbers.

Campylobacter on the surface of poultry will also decline during prolonged storage at any temperature due to drying and exposure to oxygen.

Consequently, the incidence of Campylobacter reduction during cold storage was set at 40% in the baseline model.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Preparation (G)-Salmonella	40	0	0.1	2
Preparation (G)-Campylobacter	0	0	0.1	2
Undercooking (R)-Salmonella	25	-7.0	-4.0	0
Undercooking (R)-Campylobacter				

During preparation of the poultry food for cooking it was assumed that 40% of the servings experienced severe enough temperature abuse to result in a 0 to 2 log increase in Salmonella numbers.

Cooking of poultry was modeled by considering the percentage of servings that were undercooked.

Undercooking was defined as cooking that resulted in less than 100% destruction of bacteria on the poultry serving.

Servings that were properly cooked were assumed to contain no pathogens after cooking.

For the baseline model, it was assumed that 25% of the servings were undercooked.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Cooling (C)-Salmonella	20	0	0.1	1.0
Cooling (C)-Campylobacter				
Cooling (G)-Salmonella	40	0	0.1	2.0
Cooling (G)-Campylobacter	0	0	0.1	2.0

After cooking it is possible that poultry may be recontaminated by pathogens in the food preparation environment.

The first cooling event models recontamination of cooked poultry.

In the baseline model, recontamination was defined such that 20% of poultry servings were handled in a manner that provided an opportunity for recontamination.

However, in order for recontamination to occur, the poultry serving had to be contaminated with pathogens before cooking.

The model is set up such that when recontamination occurs a certain percentage of pathogens on the serving before cooking are transfered back onto the serving after cooking.

The percentage of transfer ranges from 0 to 1%.

Following recontamination, the final pathogen event in the model is a growth event.

It was assumed that 40% of the cooked poultry servings experienced severe enough temperature abuse to result in a 0 to 2 log increase in Salmonella numbers.

The pathogen load of the poultry serving after cooling is the dose of pathogens consumed by the consumer.

At consumption, the poultry serving may be pathogen-free or it may be contaminated with Salmonella, Campylobacter, or both Salmonella and Campylobacter.

Baseline Model Settings

Input	Incidence	Extent		
	%	Min.	Mode	Max.
Infection Dose(Normal)-Salmonella	80	2	2.5	3.0
Infection Dose(Normal)-Campylobacter		2.5	3.0	3.5
Infection Dose(High Risk)-Salmonella	20	1	1.5	2.0
Infection Dose(High Risk)-Campylobacter		1.5	2.0	2.5

The probability or risk of a Salmonella or Campylobacter infection from consumption of a poultry serving is a function of the number of pathogens present and the infection dose.

Infection dose is a function of the interaction between food composition, pathogen virulence, and host resistance.

Infection dose is modeled such that users can designate the composition of the human population in terms of the percentage of individuals with normal resistance and the percentage of individuals with low resistance.

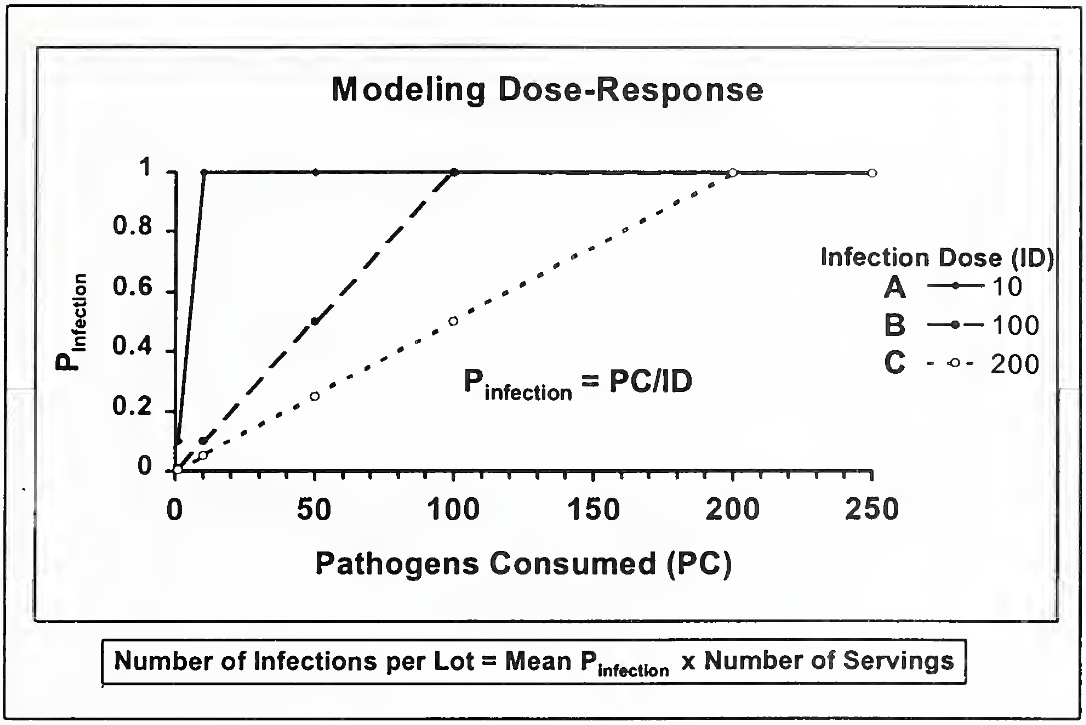
In the baseline model, the consumer population is assumed to be composed of 80% normal and 20% high risk individuals.

Another feature of the infection dose modeling method used, is that the user can assign different infection dose ranges for each pathogen.

In the baseline model, the infection dose range for Salmonella was set lower than the infection dose range for Campylobacter.

Finally, the model is set up such that it is not possible for an individual to have a normal infection dose for one pathogen and a high risk infection dose for the other pathogen.

Rather, the individual will have either a normal or a high risk infection dose for both pathogens.



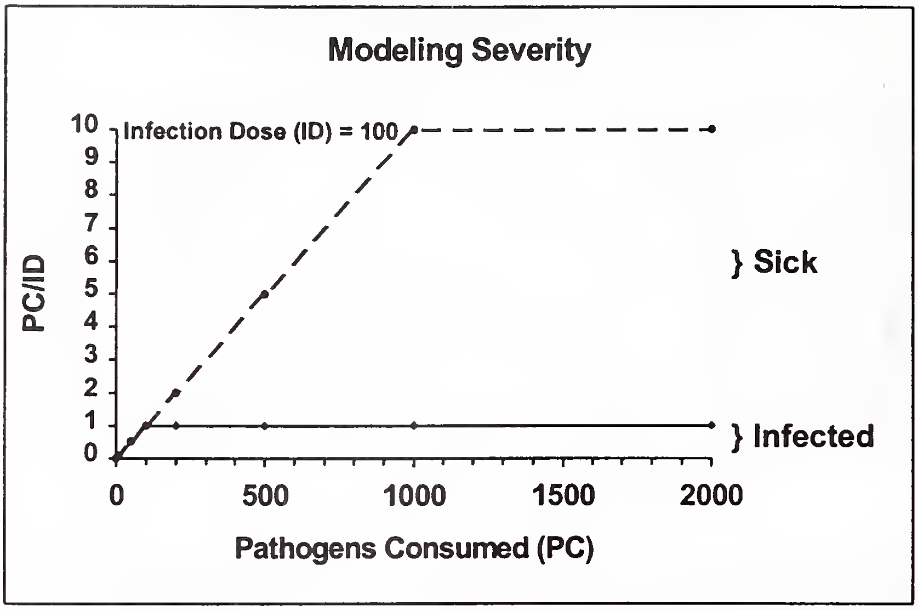
Dose-response is modeled using a linear model that is a modification of the exponential dose-response model.

Infection dose is defined as the dose of pathogen that results in a 100% probability of infection.

The linear model assumes that one pathogen can cause infection and that the probability of infection, a value from 0 to 1, is linearly related to the dose of pathogen consumed.

Dose-response curves for infection doses of 10, 100, and 200 pathogens are illustrated in this slide.

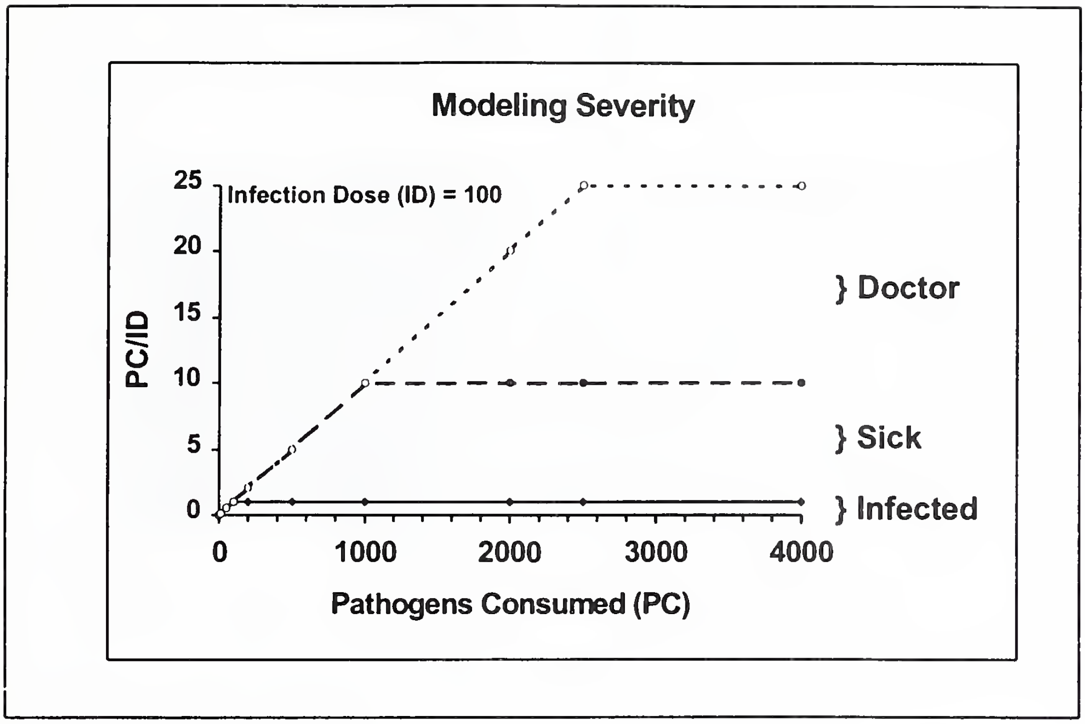
The number of cases of infection per lot of poultry food is equal to the mean probability of infection for the lot multiplied by the number of servings in the lot.



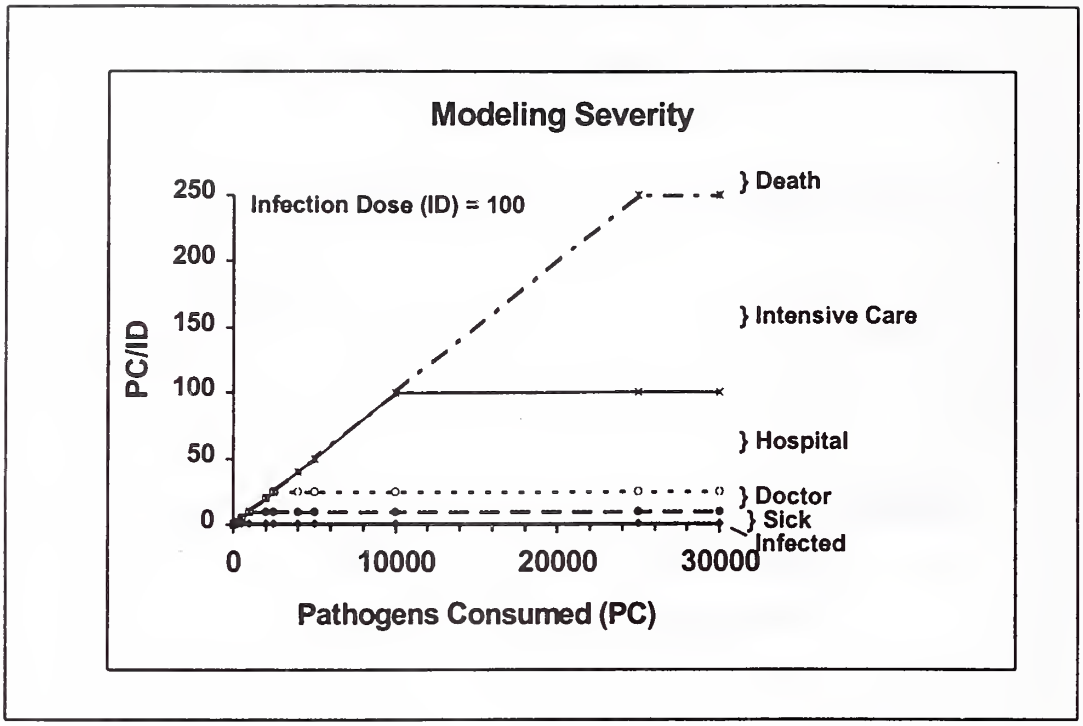
Severity of infection is modeled by extending the linear dose-response model.

This graph shows the ratio of pathogens consumed to infection dose versus the number of pathogens consumed for an infection dose of 100.

The graph indicates that an individual becomes sick when they consume between 1 and 10 times the infection dose.



When an individual consumes between 10 and 25 times the infection dose they visit their doctor.

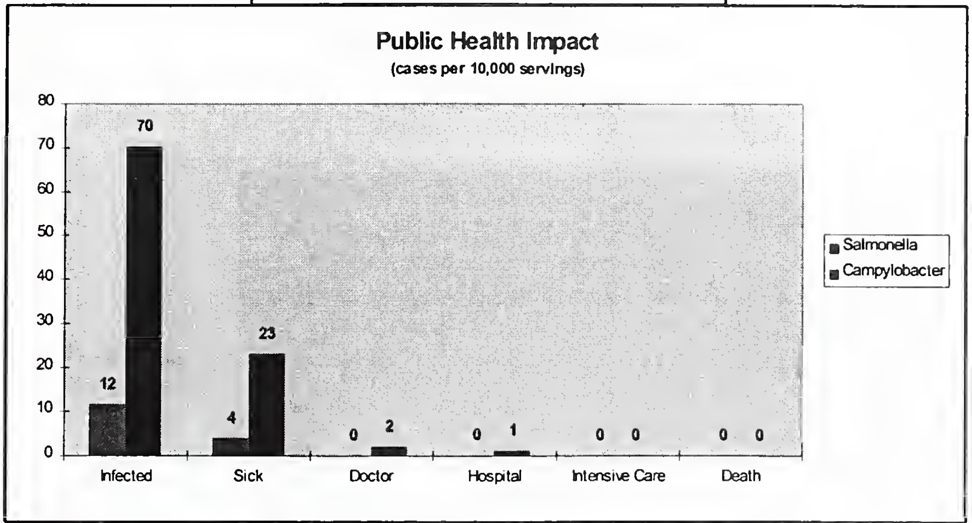


When an individual consumes between 25 and 100 times the infection dose they go to the hospital.

When they consume between 100 and 250 times the infection dose they end up in intensive care.

And when they consume over 250 times the infection dose they die.

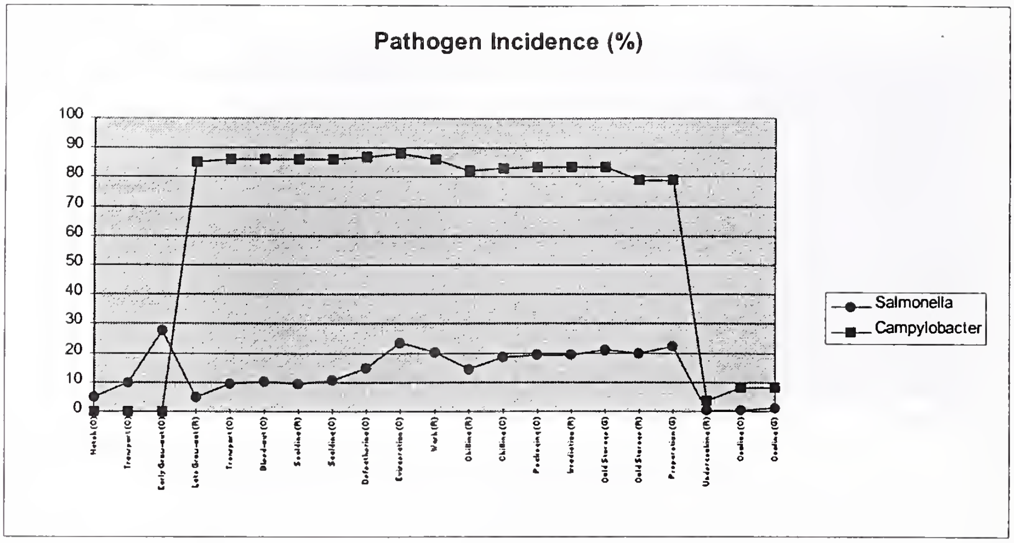
	Salmonella	Campylobacter	Total
PHI =	52	450	502



PHI = Infected + (10 * Sick) + (25 * Doctor) + (100 * Hospital) + (250 * Intensive Care) + (1,000 * Death)

To summarize the public health impact of a lot of poultry food, the model uses the equation shown here to calculate the public health index (PHI) for Salmonella, Campylobacter, and both pathogens.

Simulation Results
(Baseline)

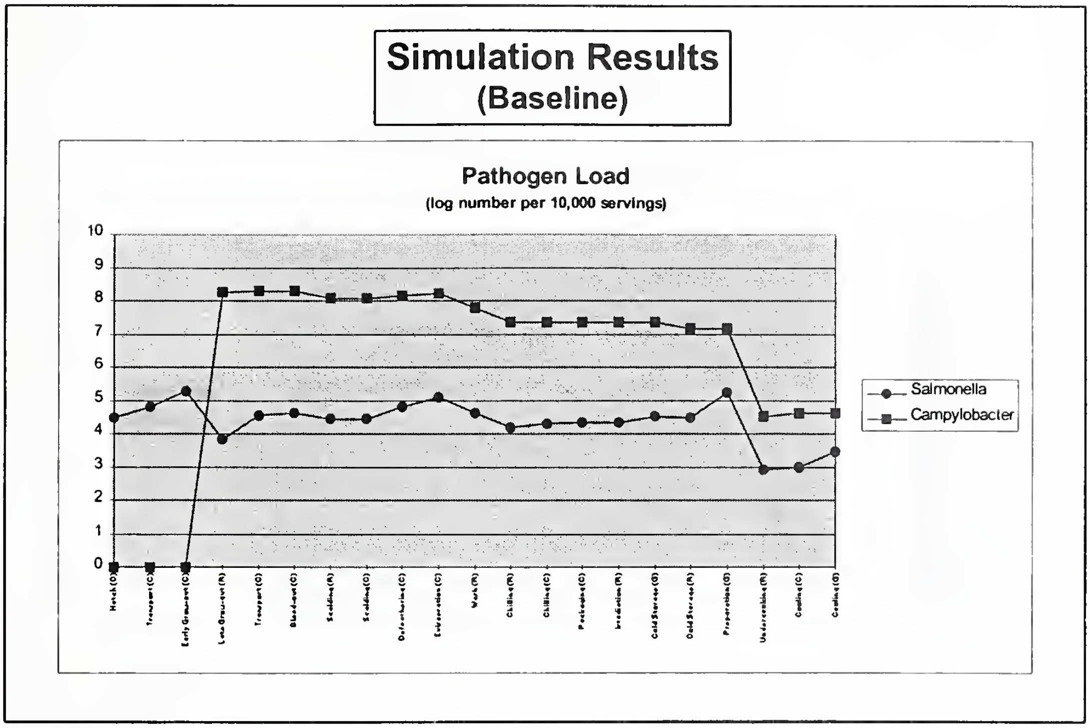


This slide shows the pathogen incidence profile for the baseline simulation.

Salmonella incidence increased to 30% during early growout, decreased to 5% during late growout, increased to 23% after evisceration, was 20% at the processing plant exit, and was 2% at consumption.

Camylobacter incidence increased to 85% during late growout, remained high throughout processing, was 83% at the plant exit, decreased to 79% during cold storage, and was 8% at consumption.

Thus, of the 10,000 servings of poultry simulated, only 200 resulted in exposure to Salmonella and only 800 resulted in exposure to Campylobacter.



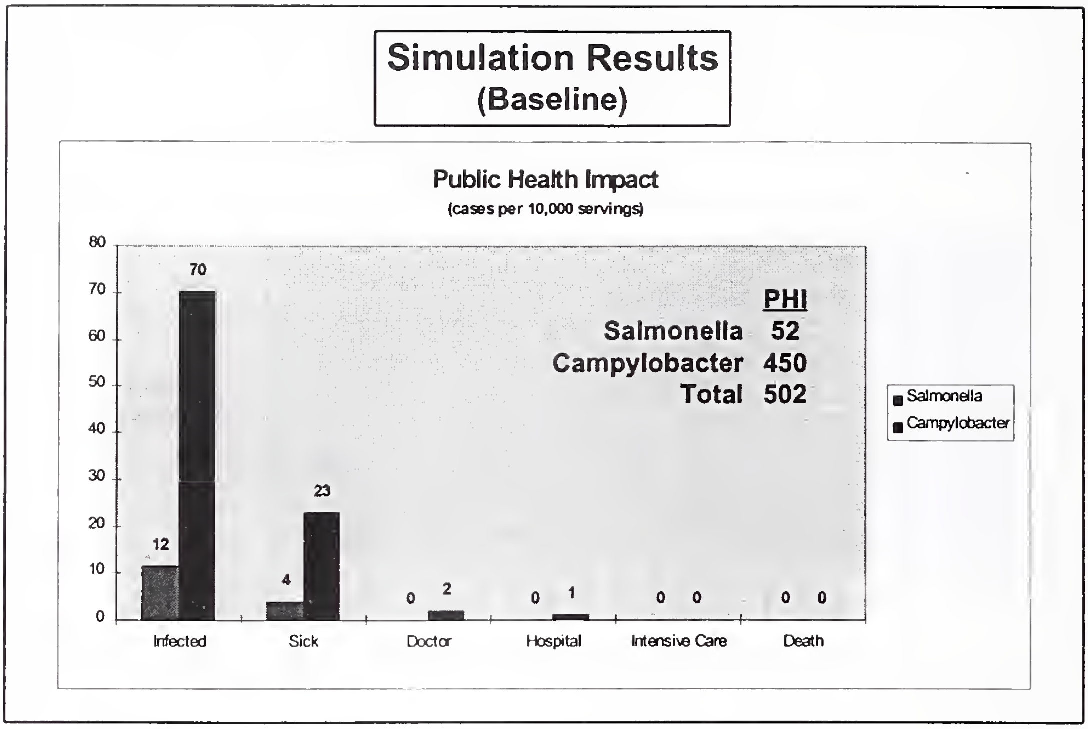
This slide shows the pathogen load profile for the baseline simulation.

Salmonella load of poultry increased during early growout, decreased during late growout, increased during early processing, decreased during late processing, increased before cooking, decreased during cooking, and increased after cooking.

Campylobacter load increased dramatically during late growout, declined during late processing, decreased during cooking, and increased slightly after cooking.

In general, Campylobacter load was much higher than Salmonella load throughout the farm to table continuum.

The 10,000 consumers in this simulation ingested 40,000 Campylobacter and 3,000 Salmonella.



This slide summarizes the public health impact of Salmonella and Campylobacter infections from poultry food in the baseline simulation.

Twelve consumers were infected with Salmonella and 70 consumers were infected with Campylobacter.

Four consumers became ill from Salmonella and 23 consumers became ill from Campylobacter.

Two consumers who became ill from Campylobacter visited their doctor and 1 of them was admitted to the hospital.

The public health index was 52 for Salmonella, 450 for Campylobacter, and 502 for both pathogens.

These results indicate that the severity of the public health impact was greater for Campylobacter than Salmonella.

Simulation Results
(Baseline)

RNGS	Public Health Index Salmonella	Campylobacter	Total
7	52	450	502
29	99	292	392
83	244	407	651
100	76	159	235
365	29	457	486
Mean	100	353	453
Change			
P Value			

The simulation results shown on the previous three slides were obtained using a random number generator seed of 7.

The random number generator seed is a number that starts the selection of numbers by a random number generator, such as @Risk.

Given the same seed, a random number generator will generate the same series of random numbers each time a simulation is run.

This slide summarizes the public health index results for five runs of the baseline model using random number generator seeds of 7, 29, 83, 100 and 365.

Note that the public health index results differ between runs of the model.

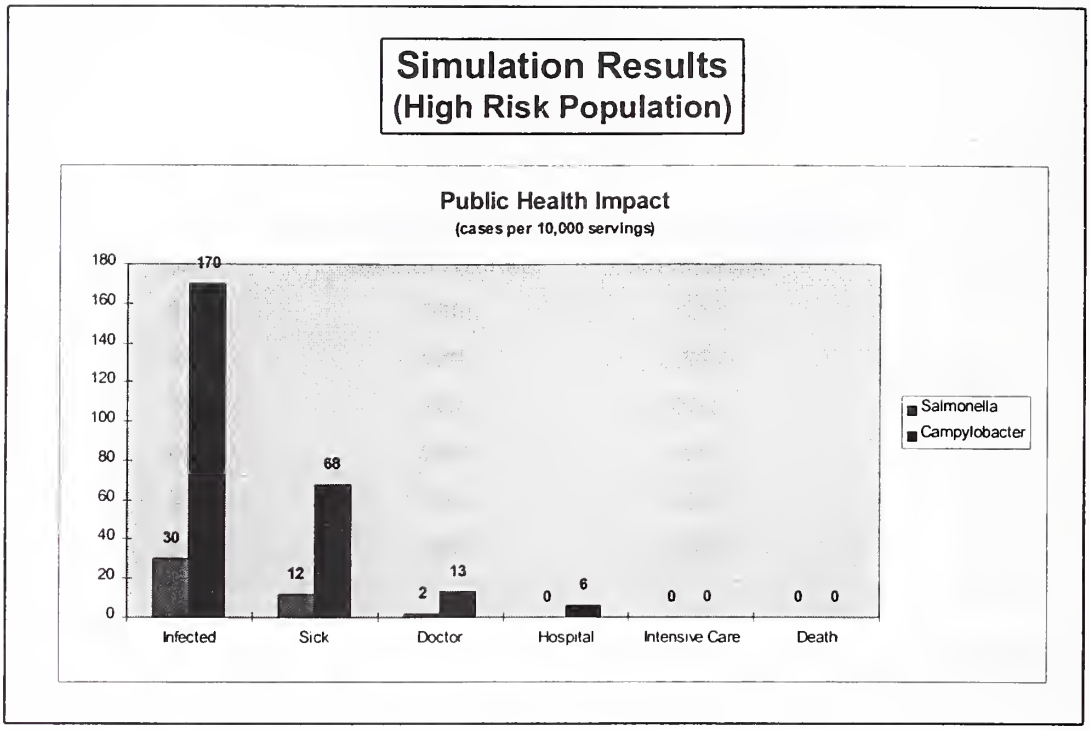
This variation is caused by the random nature of events in the model.

Assessing this variation is critical for making food safety decisions using this model.

The Stats spreadsheet in Poultry FARM-HP is where users enter public health index results for scenarios run using a common set of random number generator seeds.

The Stats spreadsheet uses a paired t-test to compare public health index results of test scenarios to a baseline scenario.

The change in the public health index and the P value of the t-test are automatically calculated in the Stats spreadsheet and function to inform users of the magnitude and direction of the public health impact change and whether the public health impact change observed is statistically significant.



To demonstrate how the simulation model can be used to make food safety decisions, I am now going to show the simulation results from several scenarios in which the baseline model was modified.

In the first scenario, the consumer population was changed from 20% high risk individuals to 100% high risk individuals.

All other settings in the model remained the same.

The objective of this simulation was to determine the public health impact of shipping the poultry food to a high risk population, such as children in the school lunch program or elderly people in a nursing home.

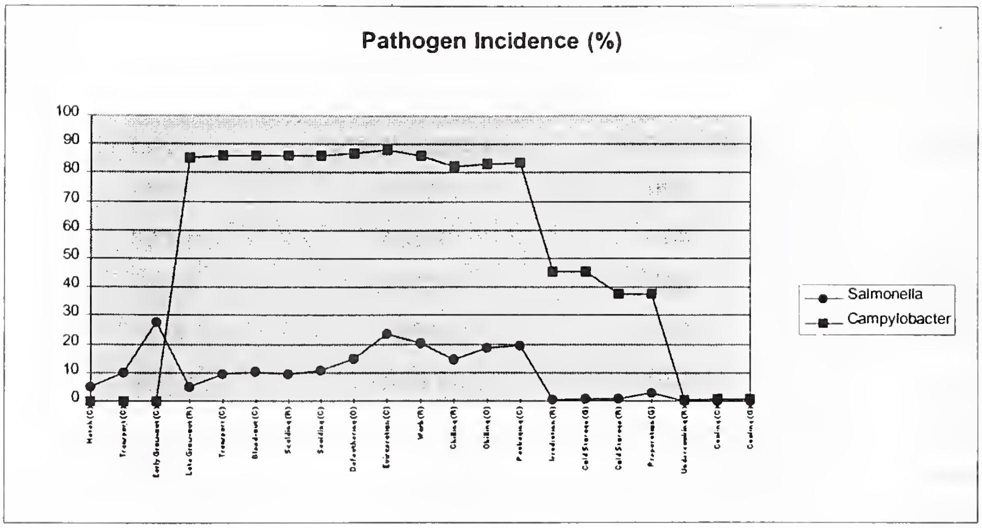
Simulation Results
(High Risk Population)

	Public Health Index		
RNGS	Salmonella	Campylobacter	Total
7	200	1,775	1,975
29	483	1,152	1,635
83	622	1,717	2,339
100	135	750	885
365	129	1,610	1,739
Mean	314	1,401	1,715
Change	+214	+1,048	+1,261
P Value	0.0374	0.0018	0.0019

The results of the high risk population simulation indicated that the public health index for Salmonella increased 214 points, the public health index for Campylobacter increased 1,048 points, and the total public health index increased 1,261 points.

Whether these public health indices indicate that the poultry food should or should not be shipped to a high risk population is a decision that would be made based on criteria established by risk managers in the poultry company and regulatory agency.

Simulation Results
(Irradiation)

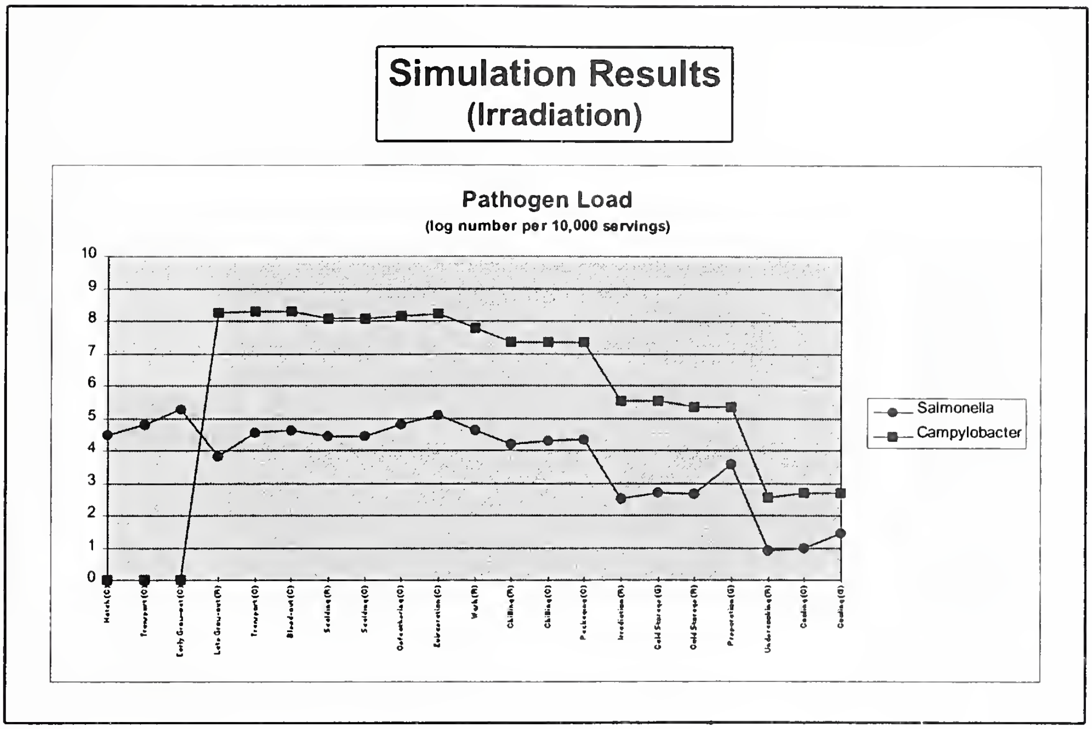


The objective of the second scenario was to determine the public health impact of irradiating poultry food at the processing plant.

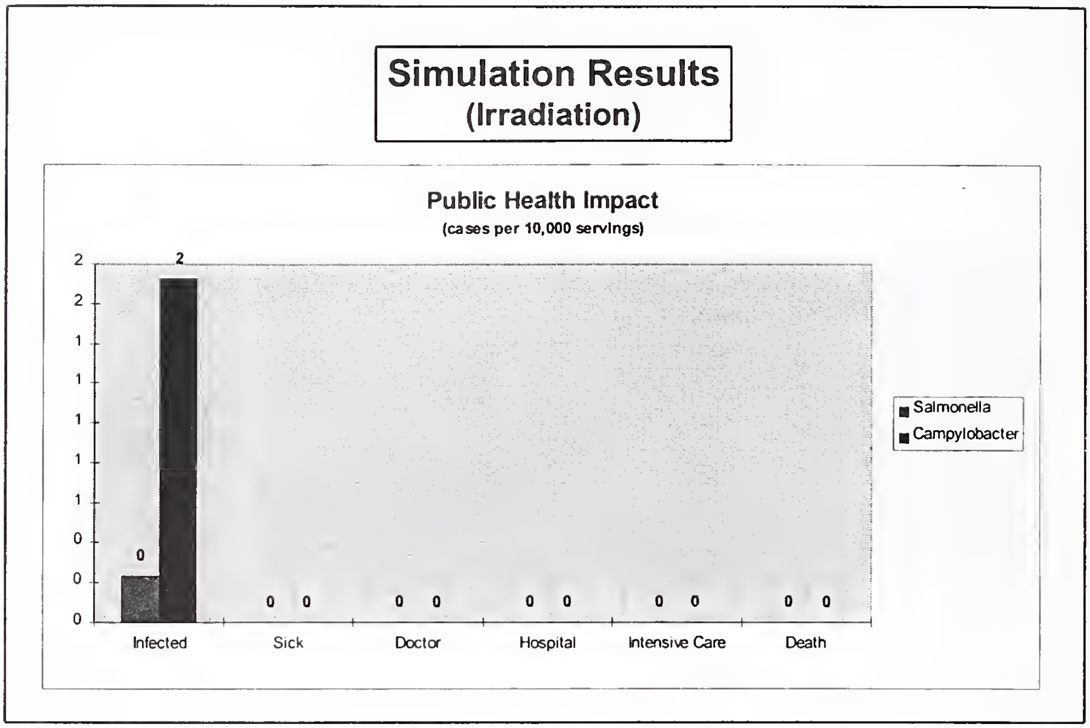
In this scenario, the incidence of the irradiation event was changed from 0 to 100%.

Irradiating the poultry food reduced the incidence of Campylobacter from 85 to 45% at the plant exit and reduced the incidence of Salmonella from 20 to 1% at the plant exit.

These reductions in pathogen incidence at the plant exit were translated into low levels (<1%) of pathogen exposure at consumption.



The total number of Campylobacter ingested by the 10,000 consumers decreased from 40,000 to 600, whereas the total number of Salmonella ingested by the 10,000 consumers decreased from 3,000 to 30.



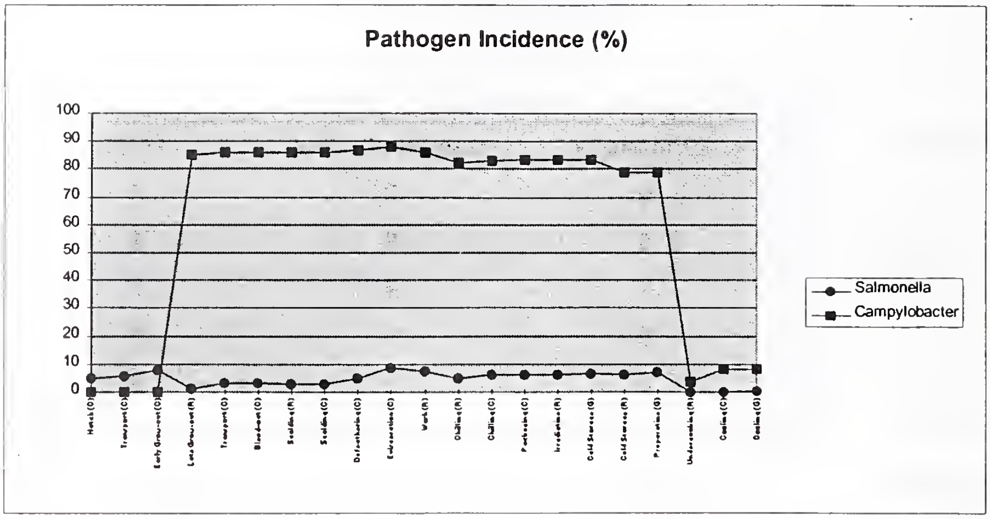
The incidence and severity of foodborne infection was greatly reduced but not eliminated by irradiation.

Simulation Results
(Irradiation)

RNGS	Public Health Index: Salmonella	Campylobacter	Total
7	0	2	2
29	0	2	2
83	1	2	3
100	0	1	2
365	0	2	2
Mean	0	2	2
Change	-100	-351	-451
P Value	0.057	0.0034	0.0027

The results of the irradiation simulation indicated that irradiation is a very effective technology for reducing the risk and severity of Salmonella and Campylobacter infections from poultry food.

Simulation Results (Competitive Exclusion)



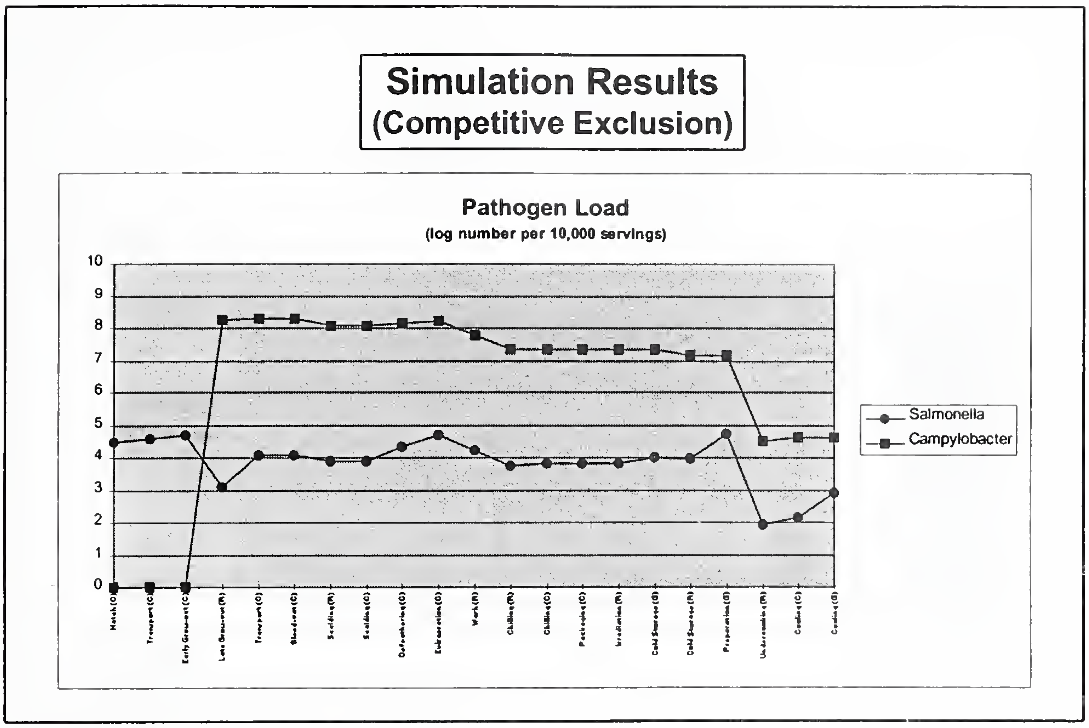
In the third scenario, the incidence of contamination events for Salmonella during production and processing were reduced by 90% to mimic the use of competitive exclusion technology in the hatchery.

Exposure of young poultry to a mixture of bacteria from adult birds reduces gut colonization by Salmonella via competitive exclusion of Salmonella from attachment sites in the intestinal tract.

Unfortunately, the mechanism of gut colonization by Campylobacter differs from Salmonella and thus, competitive exclusion is not an effective intervention method for Campylobacter.

Results of the competitive exclusion simulation indicated that the incidence of Salmonella contamination at the processing plant exit was reduced from 20% to 8%.

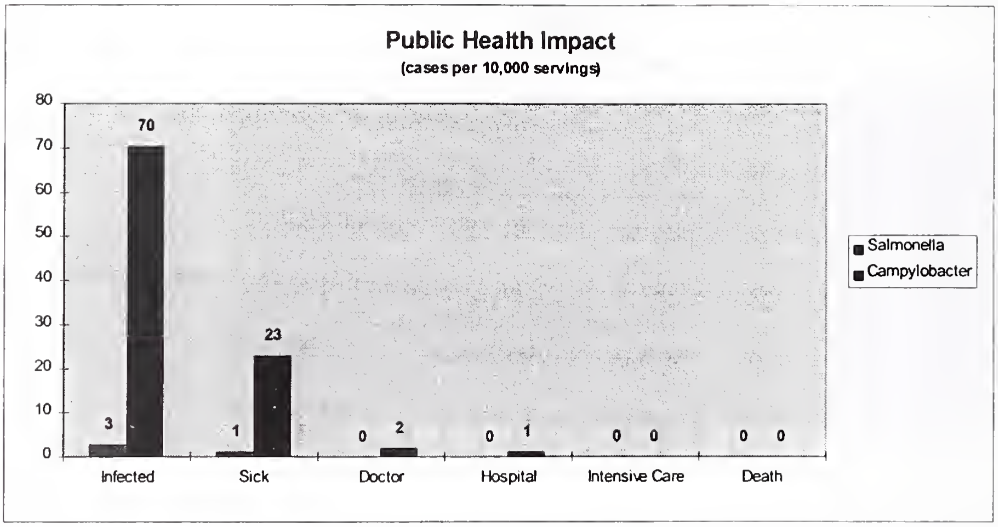
Competitive exclusion also reduced the percentage of consumers exposed to Salmonella.



Likewise, competitive exclusion reduced the total number of Salmonella ingested by 10,000 consumers from 3,000 to 1,000.

The number of Campylobacter ingested was not altered by competitive exclusion.

Simulation Results (Competitive Exclusion)



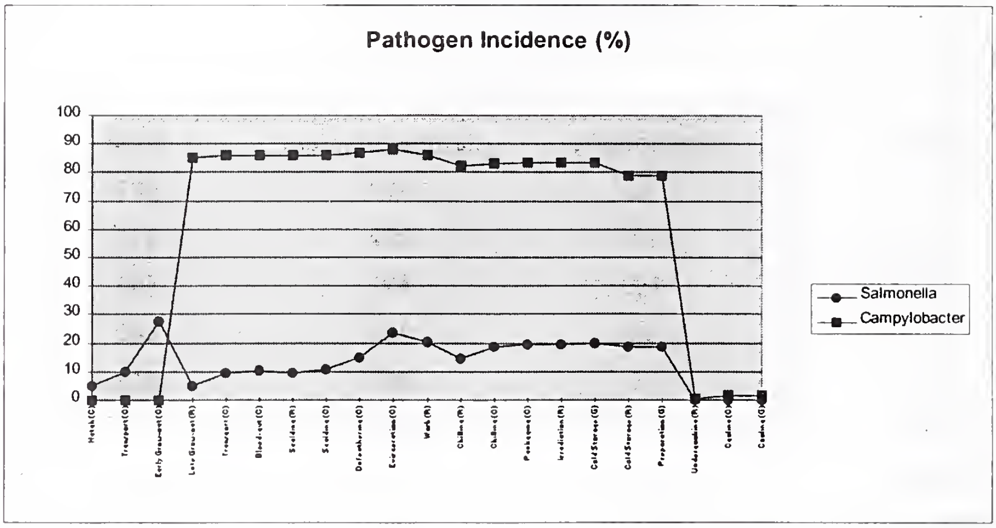
The reduced exposure of consumers to Salmonella from poultry produced using competitive exclusion was translated into a public health benefit.

Simulation Results
(Competitive Exclusion)

	Public Health Index		
RNGS	Salmonella	Campylobacter	Total
7	13	450	463
29	24	292	317
83	159	407	566
100	50	159	209
365	25	457	482
Mean	54	353	407
Change	-46	0	-46
P Value	0.0388	1.000	0.0388

The public health index for Salmonella was reduced by 46 points and even though competitive exclusion did not affect the public health index for Campylobacter, the total public health index was signficantly improved.

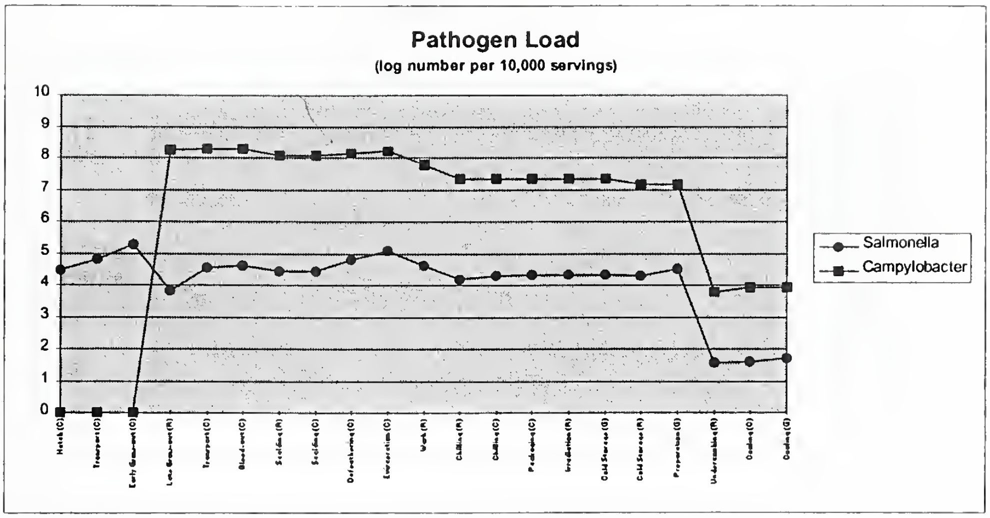
Simulation Results (Consumer Education)



In the fourth scenario, the incidence of temperature abuse, the incidence of undercooking, and the incidence of recontamination of poultry were reduced to 5% to mimic the outcome of a successful consumer education program.

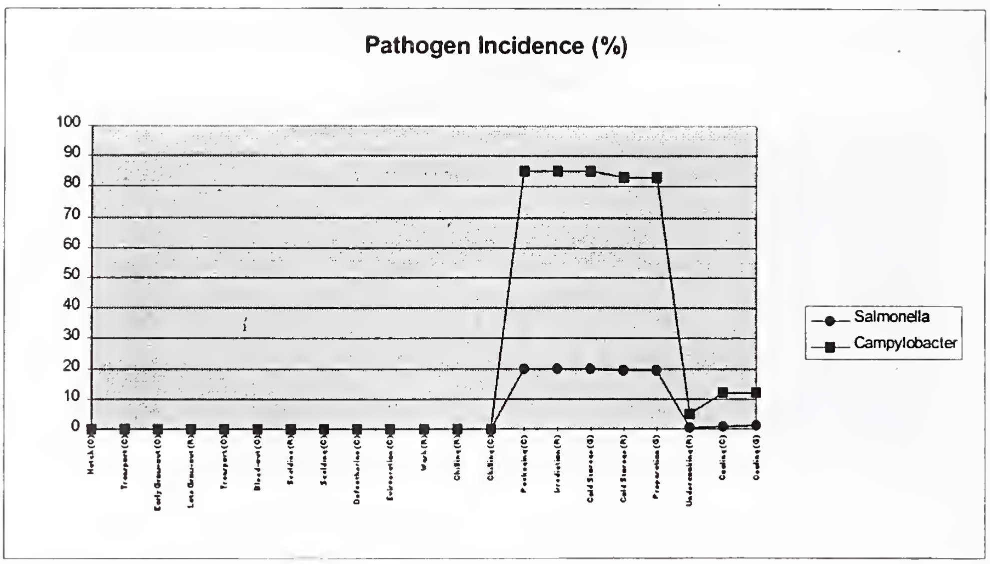
Results of the simulation indicated that consumer education significantly reduced the percentage of consumers exposed to Salmonella and Campylobacter.

Simulation Results
(Consumer Education)



Consumer education reduced the number of Campylobacter ingested by 10,000 consumers from 40,000 to 10,000 and reduced the number of Salmonella ingested by 10,000 consumers from 3,000 to 60.

Simulation Results
(Plant Exit to Table)



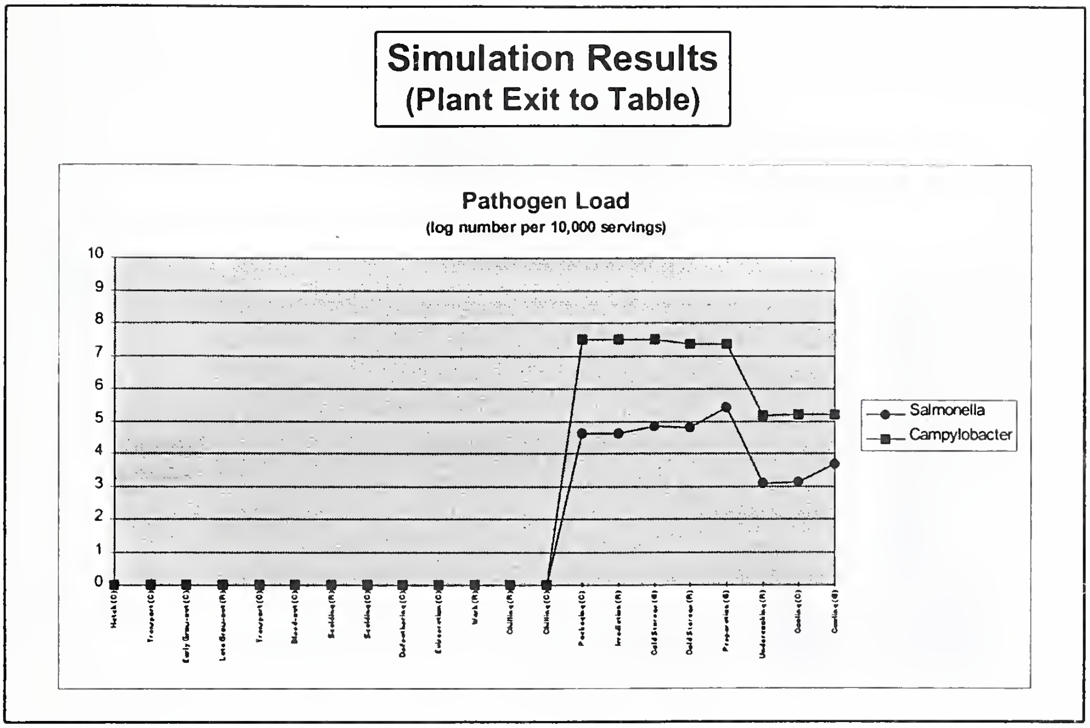
Simulations can be conducted without using the whole model.

In this simulation, the incidence of all contamination events during poultry production and processing were set to 0% to create a plant exit to table model.

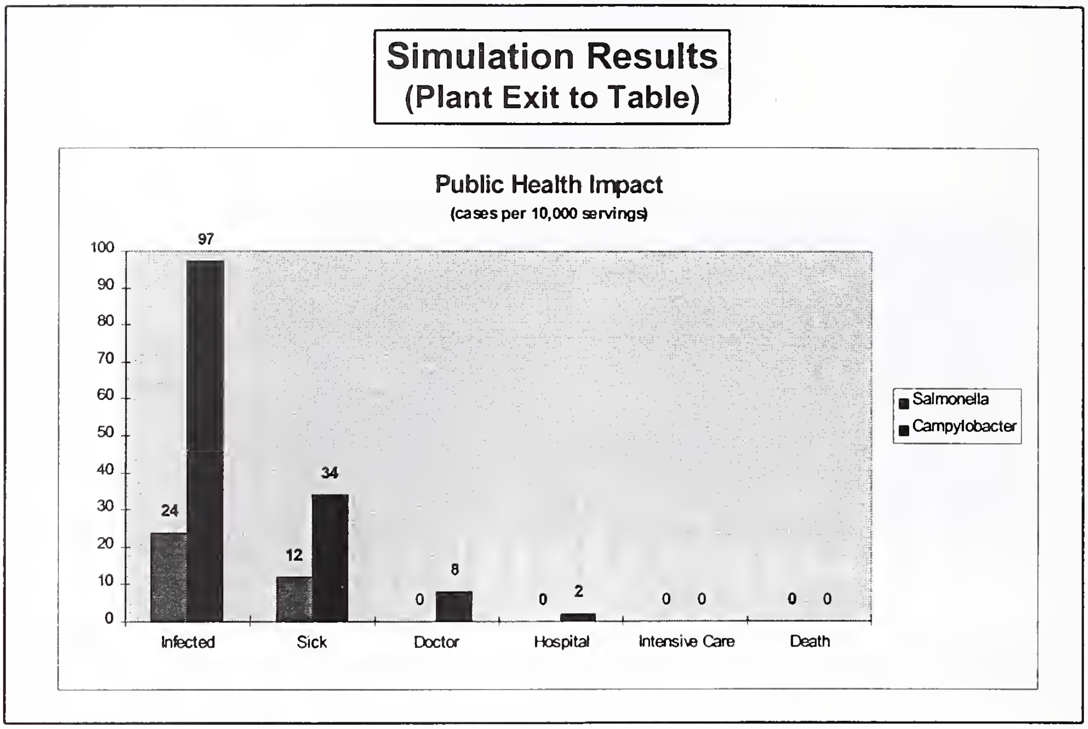
This application of the model is ideal for a poultry company that enumerates levels of pathogens in their finished product.

In this simulation, contamination of poultry at the processing plant exit was set such that 20% of the poultry servings were contaminated with 1 to 100 Salmonella and 85% of the poultry servings were contaminated with 1 to 100,000 Campylobacter.

Results of the simulation indicated that 12% of consumers were exposed to Campylobacter and 2% of consumers were exposed to Salmonella.



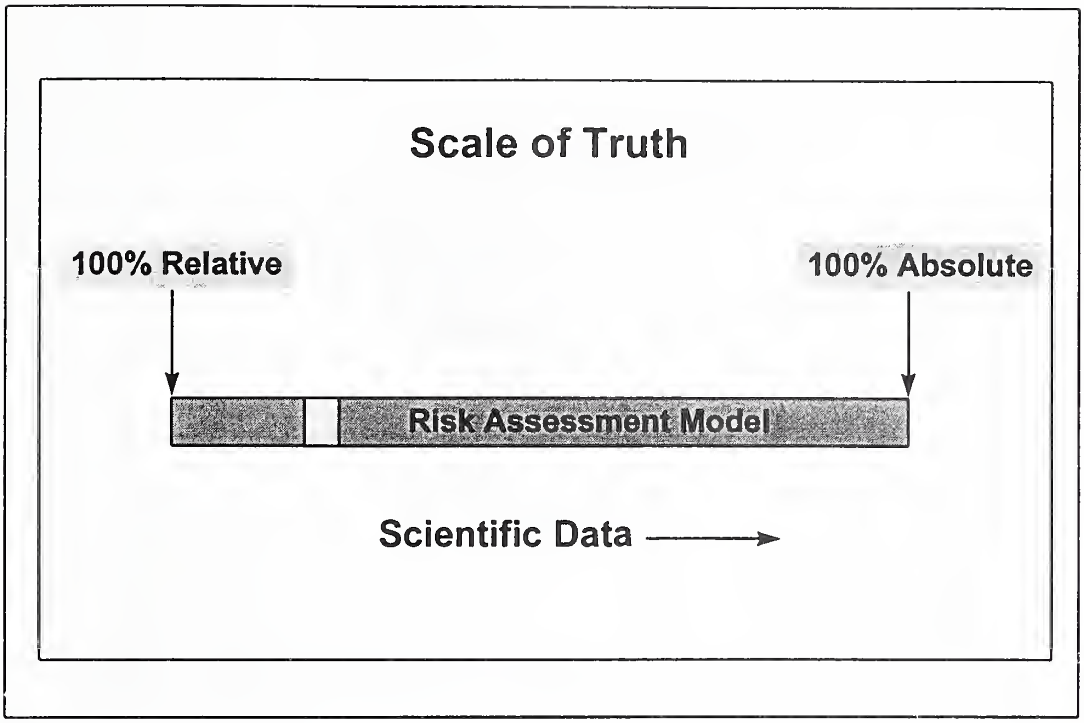
The number of Campylobacter ingested by 10,000 consumers was 160,000, whereas the number of Salmonella ingested by 10,000 consumers was 6,000.



Out of 10,000 consumers in this Plant Exit to Table simulation, 24 were infected with Salmonella and 97 were infected with Campylobacter.

Of the 24 infected with Salmonella, 12 became ill, whereas of the 97 infected with Campylobacter 34 became ill.

Only 8 cases of Campylobacter illness were severe enough to prompt a visit to the doctor with 2 of these patients being ill enough to require hospitalization.



The simulation model in Poultry FARM-HP embodies the "Field of Dreams" philosophy: "build the model and they will come" where "they" refers to scientific data.

As scientific data is collected and used to better define the settings in the model, the predictions obtained will become more absolute and less relative in nature.

Nonetheless, a primary reason for constructing this simulation model was to provide a blueprint for future research.

Research Needs

- **Pathogen Load**
  - **Enumeration Methods**
  - **Enumeration Data**
- **Infection Dose**
  - **Animal Studies**
    - **food composition**
    - **pathogen virulence**
    - **host resistance**

- **Predictive Model**
  - **Contamination**
  - **Reduction**
  - **Growth**

The research needs for this model can be divided into three areas.

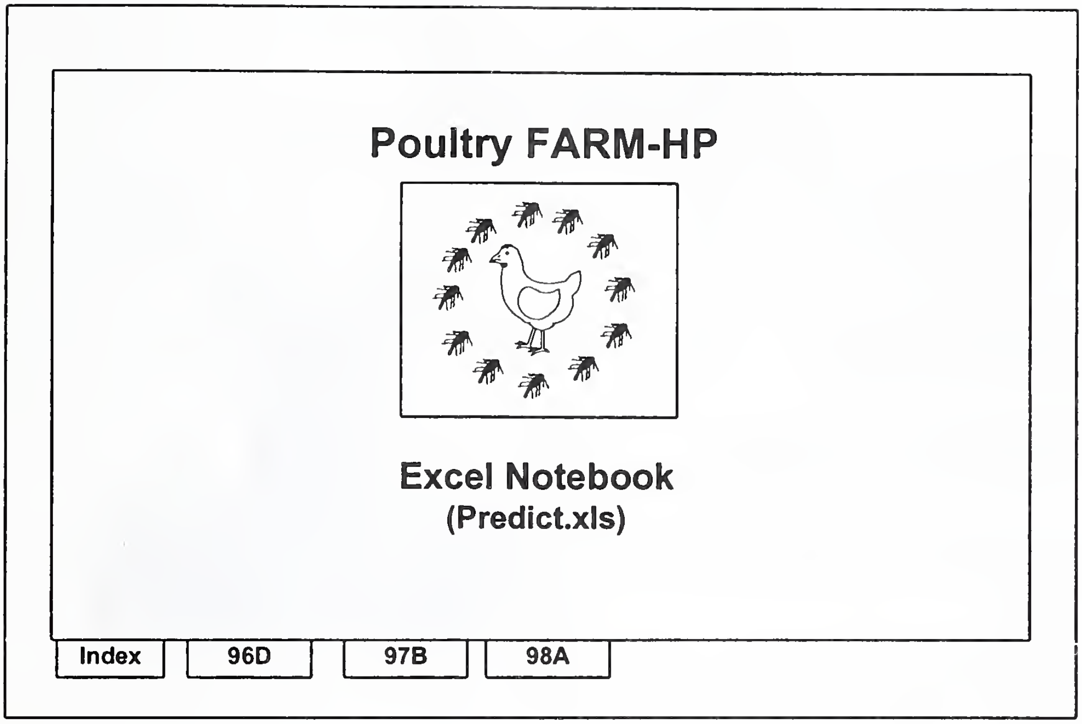
First, pathogen load research is needed to develop better methods for enumerating pathogen levels on poultry food as it moves through the farm to table continuum.

Pathogen enumeration data are needed to define model settings as well as validate model outputs.

Second, infection dose research in animal models is needed to better define relationships between food composition, pathogen virulence, and host resistance.

Infection dose data from animal studies can be used to adjust infection dose estimates from human outbreak investigations.

Third, predicitive model research is needed to develop computer models that predict changes in pathogen load as a function food and environmental factors.



In addition to the simulation model just described and demonstrated, Poultry FARM-HP contains an Excel notebook that houses predictive models.

Predictive models in Poultry FARM-HP are response surface models that predict changes in pathogen load as a function of time, temperature, and food factors.

The current version of Poultry FARM-HP contains three growth models for Salmonella.

Predictive Model 98A
(Cooked Chicken Breast)

Model Parameters					
Previous Sodium Chloride (0.5 to 4.5%)	0.5	0.5	0.5	0.5	0.5
Temperature (10 to 40C)	25	25	25	25	25
Time of Abuse, h	2	4	8	12	16
Risk Parameters					
Salmonella (number/serving)	1	1	1	1	1
Infection Dose (number)	100	100	100	100	100
Growth Characterisitics					
Lag Time, h	2.7	2.7	2.7	2.7	2.7
Specific Growth Rate, log number/h	0.40	0.40	0.40	0.40	0.40
Log Increase	0.0	0.5	2.1	3.8	5.4
Health Outcomes					
Risk of Infection	1.0%	3.4%	100%	100%	100%
Sick	No	No	Yes	Yes	Yes
Doctor	No	No	No	Yes	Yes
Hospital	No	No	No	Yes	Yes
Intensive Care	No	No	No	No	Yes
Death	No	No	No	No	Yes

This slide shows model 98A which predicts the growth of Salmonella on cooked chicken breast as a function of time, temperature, and previous sodium chloride level.

Users enter values for model parameters and risk parameters and then the model calculates the growth characteristics and health outcomes.

In this example, the effect of time of temperature abuse at 25C is evaluated for its effect on growth of Salmonella and health of the consumer.

The consumer in this scenario assumed that 1 Salmonella was present on the serving of cooked chicken breast and that the infection dose was 100 Salmonella.

At 2 h of temperature abuse, there was no change in Salmonella load and the risk of infection was 1%.

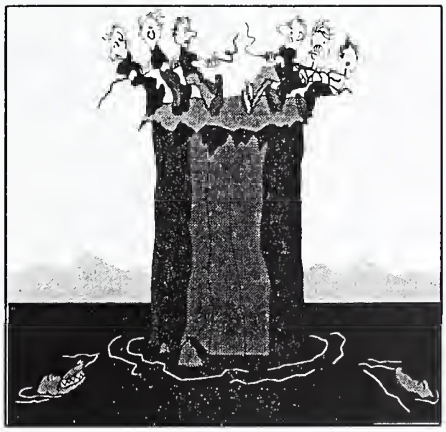
At 4 h of temperature abuse, Salmonella load increased by 0.5 log cycles and the risk of infection increased to 3.4%.

At 8 h of temperature abuse, Salmonella load increased by 2.1 log cycles and the risk of infection was 100% meaning that the consumer got sick.

At 12 h of temperature abuse, Salmonella load increased by 3.8 log cycles and the severity of the infection resulted in hospitalization of the consumer.

Finally, at 16 h of temperature abuse, Salmonella load increased by 5.4 log cycles and the severity of the infection resulted in death of the consumer.

Take Home Messages



- Everyone has a role to play.
- Computer models are a valuable tool.

Improving and maintaining the microbiological safety of poultry food should not be a tug-of-war between the poultry industry and consumers.

It is clear from the results of the computer simulations presented that everyone, from the poultry farmer to the consumer, has a role to play in ensuring the microbiological safety of poultry food.

In addition, todays presentation demonstrates that computer models are a valuable tool for helping us make important food safety decisions that impact public health.

Properly applied, computer models may provide us an objective way of avoiding a costly game of tug-of-war that could have unwanted consequences for both the poultry industry and consumers.